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The Cretaceous-Tertiary boundary in Sopelana (Biscay, Basque Country)

By

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With 6 text figures

ABSTRACT

The Sopelana section in the Basque Country (Northern Spain) is a locality with a well exposed outcrop of the Cretaceous-Tertiary boundary, like the well known Zumaya section. A detailed sequence 12 m thick has been studied, and its planktonic foraminifera and calcareous nannoplankton has been classified. The first occurrence of *Globigerina (E.) eugubina* is a few centimeters above the extinction of upper Cretaceous planktonic foraminifera. Several changes occur in the associations, of both planktonic foraminifera and calcareous nannoplankton, prior to the C/T boundary, mainly in the number of species and the abundance of specimens. A *Thoracosphaera* spp. flood occurs at the lowermost *eugubina* zone, meanwhile the planktonic foraminifera are sparse. Correlations with other sections show some minor changes in deposition rates, that make it difficult to establish the biostratigraphy of the C/T boundary.

KURZFASSUNG

Das Sopelana Profil (Baskenland, N-Spanien) zeigt gut aufgeschlossen die Kreide/Tertiärgrenze, gleichermaßen wie das Zumaya Profil. Ein Detailprofil von 12 km wurde auf planktonische Foraminiferen und kalkiges Nannoplankton untersucht. Das erste Auftreten von *Globigerina (E). eugubina* liegt wenige Zentimeter über dem Aussetzen der kretazischen planktonischen Foraminiferen. Verschiedene Schwankungen in den Vergesellschaftungen der planktonischen Foraminiferen und des kalkigen Nannoplankton (hauptsächlich in der Diversität und Häufigkeitsverteilung der Arten) treten vor der Kreide/Tertiärgrenze auf. Eine *Thoracosphaera*-Blüte findet sich in der untersten *eugubina*-Zone, während die planktonischen Formaniniferen noch dünn gesät sind. Korrelationen mit anderen Profilen zeigen einige geringfügige Schwankungen in der Sedimentationsrate, die eine genaue Biostratigraphie an der Kreide/Tertiär-Grenz erschweren.

INTRODUCTION

The Basque-Cantabric Basin in Northern Spain is limited by the Pyrenees to the east, the Asturian Massif to the west and the Ebro and Duero Basins to the south. In its northern central area there is the Flysch zone, characterised by sedimentary rocks from Albian to Middle Eocene ages, principally of a flysch nature (Figure 1).

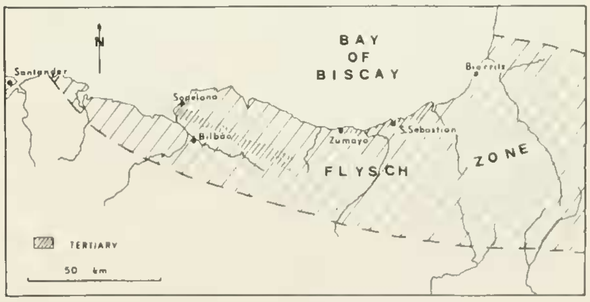

Fig. 1. Geographical and geological situation of the Sopelana section (inspired in MANGUIN & RAT, 1962).

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Flysch sedimentation is not continued in some time-intervals and geographic areas. Limestones, marlstones and marls, rich in planktonic foraminifera and coccoliths, occur in some cases like the Cretaceous-Tertiary boundary, from Upper Maastrichtian to Upper Paleocene-lowermost Eocene ages. A paleogeographical model has been proposed by PLAZIAT (1975): in this a trough oriented NW-SE received turbiditic sediments from continental margins with a prevalent calcareous sedimentation.

There are several outcrops of the C/T boundary from Bilbao to Biarritz; Zumaya, on the Guipuzcoan coast, is the best known. GÓMEZ de LLARENA (1954, 1956), HERM (1965), von HILLEBRANDT (1965), KAPELLOS (1974) and PERCIVAL & FISCHER (1977) are some of the more interesting micropaleontological papers. Another interesting locality is near Biarritz, referred to by STUART-MENTEATH (1894) and de LAPPARENT (1918), and whose nannoflora has recently been studied by PERCH-NIELSEN (1979).

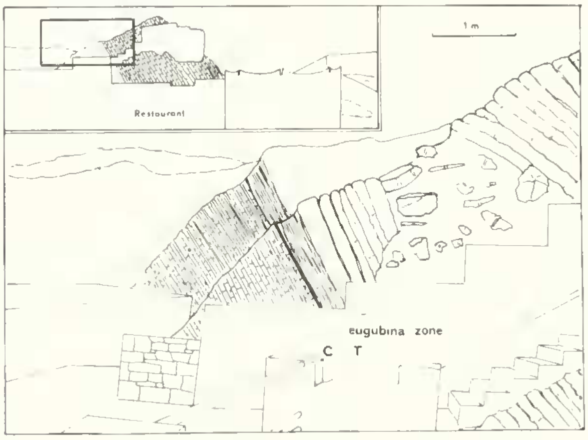

Fig. 2. The Cretaceous-Tertiary boundary in Sopelan (Basque Country).

There are other outcrops of the C/T boundary referred to in the regional bibliography of Biscay and Guipuzcoa Provinces, RAT (1959), CIRY and al. (1967), CAMPOS (1979), LAMOLDA, RODRIGUEZ-LÁZARO & WIEDMANN (1981), etc., all in the typical facies of this flysch zone. We have studied one of these, in the cliffs of Atxibiribil and Larrabasterra beaches, near Sopelana, N of Bilbao (Figure 2), referred to by de JORGE (1963), RAT (1959) and BIJVANK (1967).

Uniformity of lithology is the principal characteristic of the stratigraphic sequence of the upper Maastrichtian-Upper Paleocene ages in the coastal area of the Basque Country. Rocks of Upper Maastrichtian age show alternation of limestones and grey marls with ammonites, inoceramids, echinoids and ichnofossils, RAT (1959), WIEDMANN (1969). The top of this sequence has more marls and its colour is reddish and greenish more than grey. Foraminifera and coccoliths are always present and abundant. Above these reddish marls and marlstones there is a level, 25–40 cm thick, made up of brown grey marls that marks the basal Paleocene. Above this level, a new alternation of limestones and grey marls occurs. Red an pink colours are present in the known sections at different positions, sometimes from basal beds other times several meters above. Echinoids are found, PLAZIAT et al. (1975), and ichnofossils at several levels.

LITHOFACIES OF THE CRETACEOUS-TERTIARY BOUNDARY IN SOPELANA

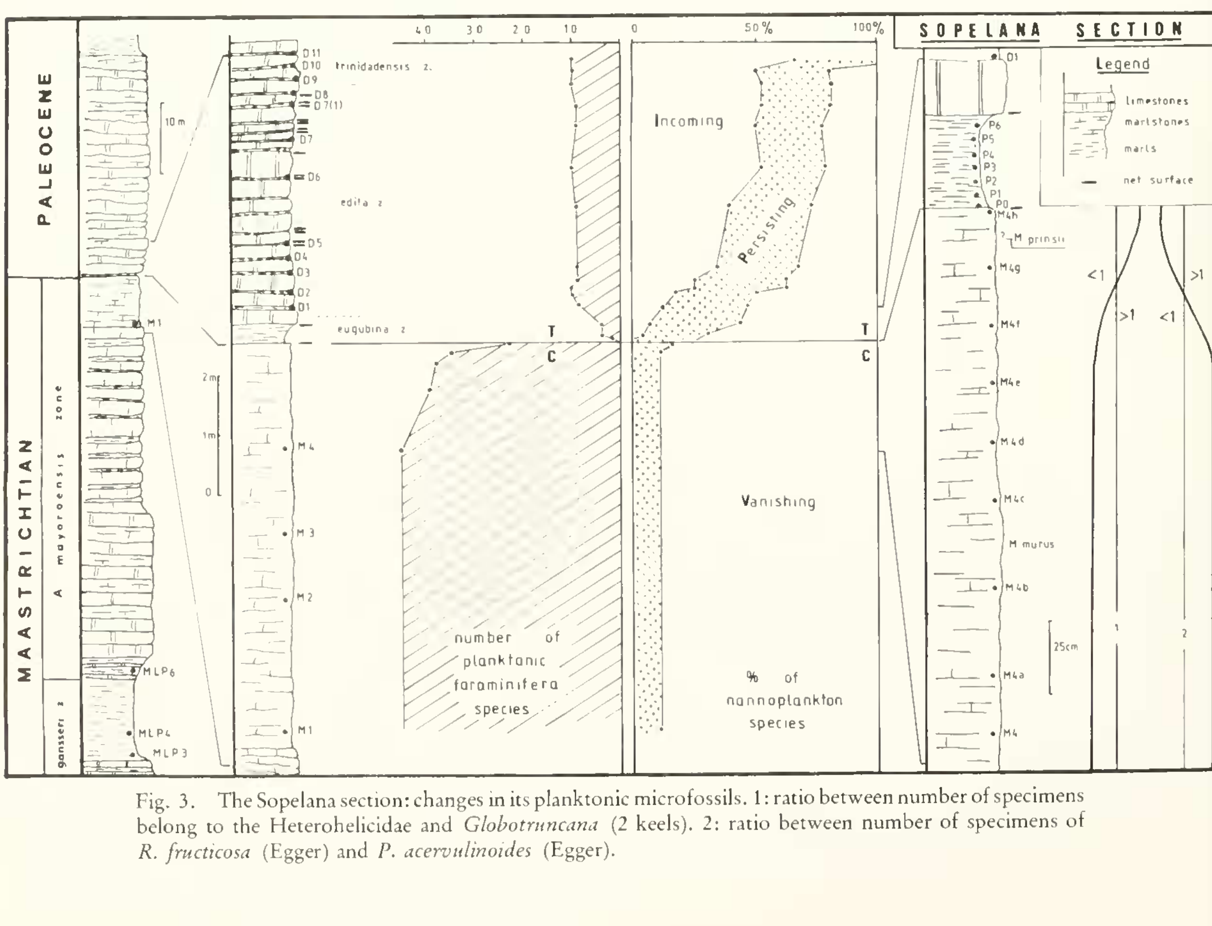

Fig. 3. The Sopelana section: changes in its planktonic microfossils. 1: ratio between number of specimens belong to the Heterohelicidae and *Globotruncana* (2 keels). 2: ratio between number of specimens of *R. fructicosa* (Egger) and *P. acervulinoides* (Egger).

The studied detailed section is 12 m thick, from latest Maastrichtian to Lower Paleocene age. The upper Maastrichtian *A. mayaroensis* zone is 55 m thick (Figure 3) with reddish and purple marls and an important intercalation of grey limestones and marls. The rate of sedimentation is 30 bubnoff (30 m/M. y.), for a duration of *A. mayaroensis* zone of 1,8 M. y., which is slower than in Zumaya, 40–80 b. according to Percival & Fischer (1977).

The top of the purple marls has a distinct burrowed surface. Organic activity of detritivorous animals is high, as is shown by the many, partially disolved foraminiferal tests found in these beds, either isolated or in tubular clusters.

Above the purple marls are 32 cm of brown grey marls; the basal 2 cm are richer in clay and their colour is browner. They represent the start of paleocene times. Above this bed one finds an alternation of grey and pink limestones, mostly micritic and marls. Thickness of beds is about 20–30 cm for the limestones and 2–4 cm, exceptionally 10 cm, for the marls, bed boundaries are distinct in the basal part, later they become gradual. The rate of sedimentation is near to 4 bubnoff for a duration of *G. (E.) edita* Zone of 1 M. y. This rate is 7 to 8 times slower than in the Upper Maastrichtian age. In general, the rate of sedimentation is 2–3 times slower in Sopelana than in Zumaya.

BIOSTRATIGRAPHY

The *A. mayaroensis* Zone, *G. (E.) eugubina* Zone, *G. (E). edita* Zone and *G. (E.) trinidadensis* Zone of planktonic foraminifera have been found in the Sopelana section. In addition the calcareous nannoplankton zones of *M. murus*, *M. prinsii*, *M. inversus* and *C. tenuis* have been identified. The presence of *C. danicus* zone is uncertain because no typical *C. danicus* has been found in the section.

Foraminifera. These are found in rich associations, mainly in *A. mayaroensis* Zone. Planktonic foraminifera are dominant throughout the Sopelana section, only in the Lowermost Paleocene are benthonic foraminifera more abundant than planktonic ones. The number of planktonic foraminifera species found in *A. mayaroensis* Zone is 47, mostly with few specimens. The more abundant and common species are: *Globotruncana arca* (Cushman), *Globotruncanita stuartiformis* (Dalbiez), *Globotruncana contusa* (Cushman), *G. falsostuarti* Sigal, *Globotruncanella havanensis* (Voorwijk), *Racemiguembelina fructicosa* (Egger), *Planoglobulina acervulinoides* (Egger), *Pseudotextularia elegans* (Rzehak), *Heterohelix* spp., etc. The species *Abathomphalus mayaroensis* (Bolli), although generally present, is not abundant and we have found no specimens in the last 1,5 m of the purple marls.

The lower boundary of *A. mayaroensis* Zone is defined by the appearance of that species, the upper boundary is defined by the extintion of the Cretaceous planktonic foraminifera. The foraminiferal association of the lower part of *A. mayaroensis* Zone is dominated by a species of *Globotruncana*, such as the *G. arca* and *G. falsostuarti* groups. Other specimens have been identified as *G. insignis*, *G. rosetta*, *G. stephensoni*, *G. patelliformis and* G. walfischensis. Toward the upper part of this zone, the spiroconvex species, such as *G. orientalis*, *G. esnehensis*, *G. patelliformis*, *G. walfischensis and Globotruncanella piramidalis* occur in higher numbers. We have observed several changes in the planktonic foraminiferal association in the last half meter of purple marl: *a)* the Heterohelicidae are more abundant than twin keeled *Globotruncana* spp., which were the more abundant species during most of the *A. mayaroensis* Zone; *b) R. fructicosa* is replaces by *P. acervulinoides* as the dominant species among the Heterohelicidae; *c)* a slight, gradual decrease in planktonic foraminifera is noted, from 95% to 87%; *d)* the number of planktonic foraminifera species decrease from 45–44 to 26 in the last sample of Maastrichtian age, in which we have not found *G. contusa*, *G. havanensis*, *T. scotti* and *R. rotundata*. *R. fructicosa* is reduced in number by a factor of 3.

Globigerina (Eoglobigerina) eugubina Zone: this is represented by the grey marls above the purple marls of the uppermost Maastrichtian age. Its lower boundary is defined by the extinction of cretaceous Globigerinacea, in Sopelana, the first appearance of *G. (E.) eugubina* is later (Figure 4), like that of *G. (E.) fringa*. Four species have been found in the *G. (E.) eugubina* Zone, always with few specimens. The upper boundary is defined by the appearance of *G. (E.) edita*. Below the first definite occurrence of *G. (E.) edita* there is a limestone bed, 27 cm thick, which in thin section shows some specimens referable to this species. Therefore, the exact position of the boundary is not well marked.

In addition to these Paleocene species specimens of upper Maastrichtian foraminifera, are present, ofter showing signs of dissolution. These specimens decrease in number toward the top.

G. (E.) edita Zone: The lower boundary is defined by the first occurrence of the species *Globigerina (Eoglobigerina) edita* in marls. The planktonic foraminifera association have as main species: *G. (E.) triloculinoides*, *G. (E.) varianta* and *G. (E.) taurica*. The species *G. (E.) pseudobulloides* is not well represented, therefore we have prefered *G. (E.) edita* to define its equivalent biozone. The upper boundary is defined by the first occurrence of *G. (E.) trinidadensis*, marker of the next zone.

In the lower part of the *G. (E.) edita* Zone some species from the *G. (E.) eugubina* Zone can be found. The upper part is characterised by the occurrence of *G. (P.) compressa* in addition to the main species previously cited. We have determined 12 species of planktonic foraminifera in this zone.

G. (E.) trinidadensis Zone: The lower boundary is defined by the first occurrence of the species *Globigerina (E.) trinidadensis*. That first occurrence is not well defined because of a limestone bed, 26 cm thick, which presents the same problem as the first occurrence of *G. (E.) edita*. We have only studied the lower part of this zone; its planktonic foraminifera associations are characterised by the occurrence of *G. (E.) trinidadensis* and *G. (E.) incostans*, in addition to the species already present in the *G. (E.) edita* Zone, which are the main ones.

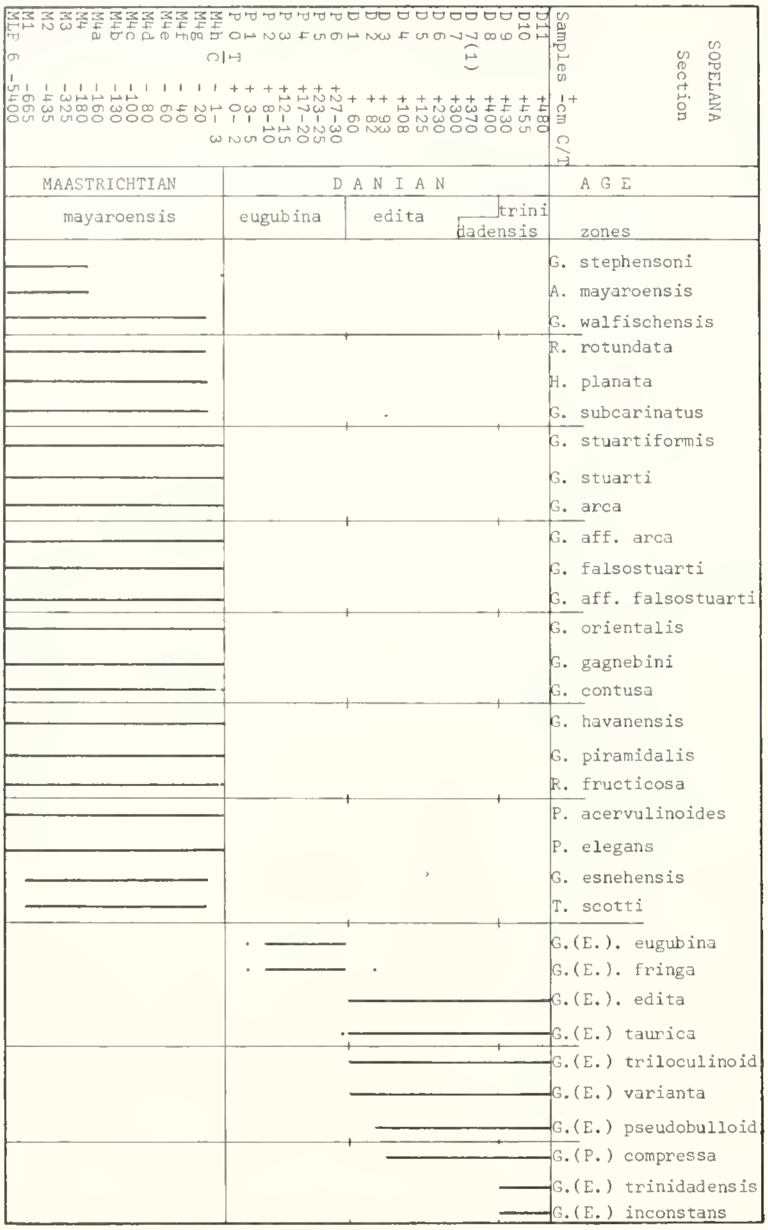

Fig. 4. Record of the planktonic foraminifera in the Sopelana section.

Nannoplankton: In the Cretaceous part of the Sopelana section, the nannoplankton biozones of *Micula murus* and *Micula prinsii* have been determined, the last only a few cm thick. Both zones have similar associations of coccoliths, the main species being *Arkhangelskiella cymbiformis*, *Cribrosphaera ehrenbergii*, *Micula decussata*, *Prediscosphaera cretacea* and *Watznaueria barnesae*. Only the occurrence of *Micula prinsii* in the uppermost Maastrichtian, distinguishes its zone from that of *M. murus*. Species with long stratigraphical occurrence, generally considered as a persisting type which passed the cretaceous/Tertiary boundary, such as *Cyclagelosphaera reinhardtii*, are very rare in the upper Cretaceous of Sopelana and they start to occur regularly from the *M. prinsii* Zone (Figure 5).

Markalius inversus Zone – NP 1

The lower boundary of this zone has been redefined several times since its discovery. At first it was based on the appearance of *Markalius astroporus* by HAY & MOHLER (1967), substituted by that of *Biantholithus sparsus* by PERCH-NIELSEN (1969) and then by the extinction of *Arkhangelskiella cymbiformis* and other Cretaceous species by MARTINI (1971). The first definition was proved invalid as *M. astroporus* is already present in the Upper Cretaceous. The second is difficult to use as it is based on a species which is usually rare. Finally, the Cretaceous extinction line is somewhat ambiguous. A new criterium introduced by ROMEIN (1979) puts the lower limit of the first Tertiary nannoplankton zone in correspondence to the mass occurrence (or increased frequency) of *Braarudosphaera bigelowi* and/or *Thoracosphaera operculata*. Using this definition, which is the only one applicable to our section, we place the lower limit of NP 1 Zone between the M4h

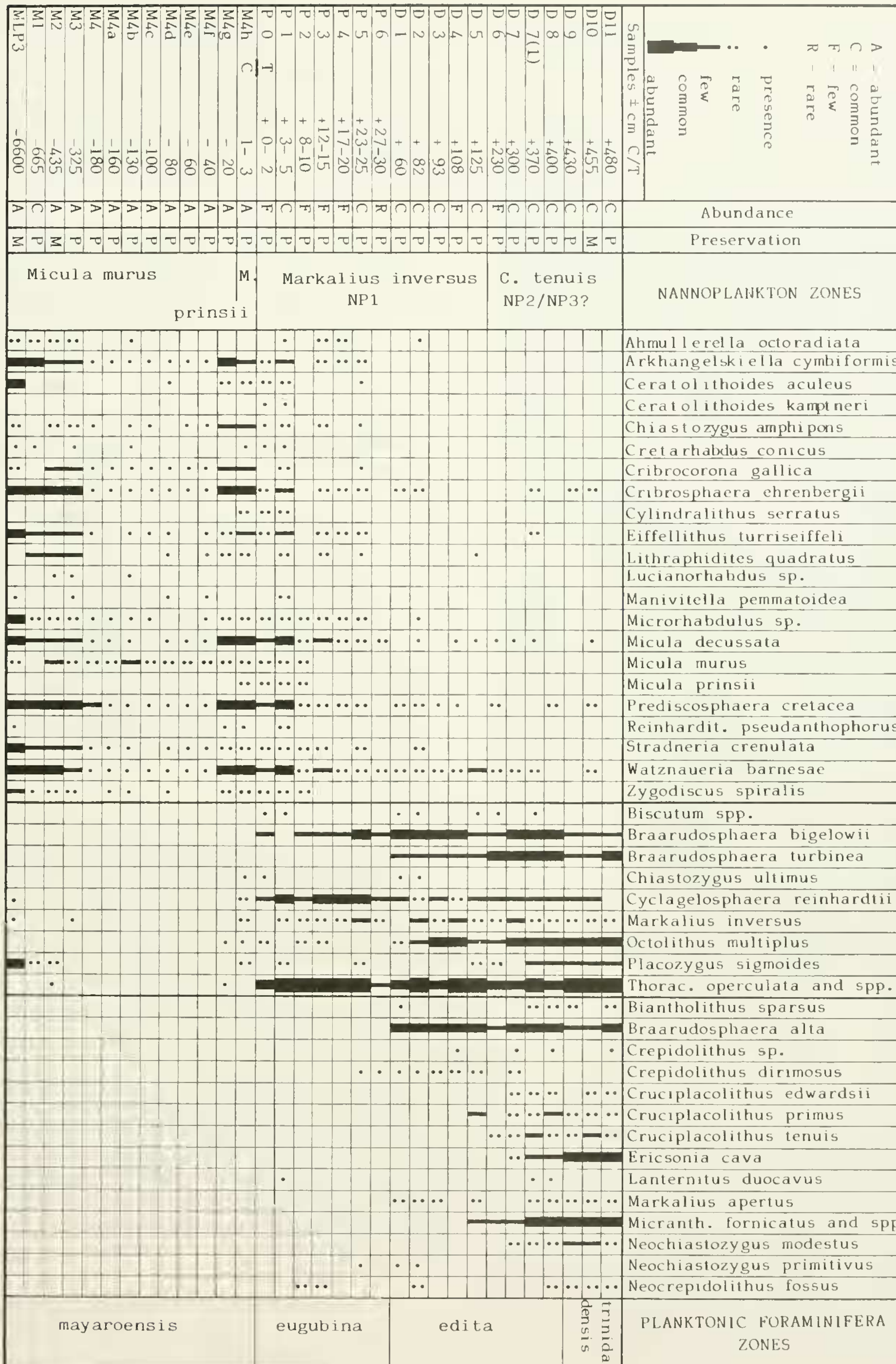

Fig. 5. Record of the calcareous nannoplankton in the Sopelana section.

and PO samples, that is between the purple and the grey marls. The lower boundary is characterized by a *Thoracosphaera* spp. flood associated with the uppermost Cretaceous coccoliths and by a marked increase in the frequency of the persisting species *Cyclagelosphaera reinhardtii.* Apart from these differences the association of the basal part of the grey marls is the same as that of the purple marls. Cretaceous coccoliths are found everywhere in the basal levels of the Tertiary and are commonly considered as reworked. In general this presence is sporadic and/or of low frequency. In our case, however, this hypothesis of reworking is hard to uphold and we belive that the most characteristic and widespread species of the Upper Maastrichtian pass beyond the lower limit of the NP 1 zone, defined according to ROMEIN (1979). Therefore, based on nannofossil associations, there exist a continuity between the top of the purple marls and the beginning of the grey marls. The drastic reduction of the Cretaceous species takes place inside the grey marls, between samples P1 and P2, and we believe that from sample P2 on the Cretaceous forms can be on the whole considered as reworked. Also, the first true Cenozoic species appears at this time, when specimens of Cretaceous species become rare in the associations.

A first increase in the frequency of *Braarudosphaera* takes place in the upper part of the grey marls, in sample P5. This phenomenon increases from sample D1 on, where several species of *Braarudosphaera,* such as *B. bigelowii, B. turbinacea* and *B. alta* have been recognized. The type of the last-named species comes from the Lower Paleocene of the Barranco del Gredero (Murcia) section in the SE of Spain. The first definate occurrence of *Biantholithus sparsus* was noted in sample D1, where also *Markalius apertus* appears. This last-named species was described from the upper part of the basal Danian D1 zone of Denmark by PERCH-NIELSEN (1979). So its occurrence in our section allows a correlation between the grey marls and the lower part of the NP1 zone in the type Danian. The first specimens of *Cruciplacolithus primus* appears in sample D5 and at same time *Micrantholithus* enters the associations. The main species of the *M. inversus* Zone of Sopelana section are *Thoracosphaera* spp. and *C. reinhardtii* for the lower part associated with *Braarudosphaera* spp., *Octolithus multiplus,* and rare incoming Cenozoic species in the upper part of the zone.

Cruciplacolithus tenuis Zone – NP2/NP3?

The first occurrence of *C. tenuis* in sample D6 marks the lower boundary of this zone, it falls in the middle part of the *G. (E.) edita* Zone of planktonic foraminifera. Besides common persisting forms of the underlying zone, *Ericsonia cava* and *Micrantholithus fornicatus* are the main species associated with the growing group of the incoming Cenozoic forms. No typical specimens of *Chiasmolithus danicus* were found in the examined samples of this section. However,' the presence of *Neochiastozygus modestus,* which according to PERCH-NIELSEN (1981) evolves from *N. primitivus* in Zone NP3, suggests that sediments of this age could be represented in the upper part of the section.

SIMILARITIES AND DIFFERENCES WITH OTHER SECTIONS

The lithology of the Sopelana section is similar to the lithology of the classical section of Zumaya, also to the section of Biarritz studied by PERCH-NIELSEN (1979) and the section of Lattengebirge in the Calcareous Septentrional Alps studied by HERM, HILLEBRANDT and PERCH-NIELSEN (1981). All these sections have a marls bed related with the C/T boundary. Other well known sections, such as Gubbio (Italy), LUTERBACHER & PREMOLI SILVA (1962), and Caravaca (SE Spain), ABTAHI (1975) and SMIT (1977), show slight differences: the former is more calcareous and the latter is richer in clay. These sections have a burrowed level, sometimes hardened, in which most species, or all, of the upper Cretaceous planktonic foraminifera are extinguished.

According to SMIT & TEN KATE (in press) the occurrence of a zone without fossils between the mass-extintion of Cretaceous planktonic foraminifera and the first sure occurrence of Cenozoic species is quite common. The Sopelana section shows the first definate specimen of *G. (E.) eugubina* 8–10 cm above the Burrowed surface of the purple marls, although there are, in that interval, some specimens which might be referable to *G. (E.) eugubina* and *G. (E.) fringa.* Therefore, the Sopelana section has strong similarities with the Zumaya, Biarritz and Lattengebirge sections, but in the last case there is an interval with *G. (E.) fringa* and without *G. (E.) eugubina.* Therefore, we have not identified a *Guembelitria cretacea* zone, SMIT (in press). The poor state of preservation of the upper Cretaceous planktonic foraminifera found in our *G. (E.) eugubina* Zone has led us to think they are not "in situ".

The nannofossil species in Sopalana C/T boundary are similar to those of the Lattengebirge, Zumaya and Biarritz section, mainly due to the large numbers of specimens of *Thoracosphaera* spp. following the extinction of Cretaceous planktonic foraminifera species. However the occurrence of *M. prinsii* in the Biarritz section is different, as it occurs here over several meters, whereas in the Lattengebirge and Sopelana sections it only occurs in a thickness of 10–15 cm on both sides of the C/T boundary.

The occurrence in the lowermost grey marls at Sopelana of *Thoracosphaera* spp. with Cretaceous coccoliths species in similar relative abundance as in the upper Cretaceous beds and without Cenozoic coccoliths species, has led us to think there are levels in Sopelana not represented in Biarritz, or that there is more reworking of Cretaceous fossils in Sopelana than in Biarritz. The Zumaya and Sopelana sections however show the same associations.

There are some differences between Sopelana, Zumaya and Lattengebirge sections during the Paleocene age. Associations have not allowed us to make subdivisions within the *M. inversus* Zone (NP1) as they did in Lattengebirge. *Chiasmolithus danicus* was not found whereas it seems to occur in Zumaya, PERCIVAL & FISCHER (1977), although it occurs here at the same level as *C. tenuis.*

Differences to Biarritz are clear, the *M. inversus* (NP1) Zone is 1 m thick, whereas in Sopelana it is 2 m. This difference is contrary to what can be observed in the top of the Maastrichtian; an explanation for this could be a change of the rate of sedimentation near the C/T boundary, or different erosion in the uppermost Maastrichtian and lowermost Paleocene of both sections.

CONCLUSIONS

The biostratigraphy we have recognised – the *A. mayaroensis, G. (E.) eugubina, G. (E.) edita* and *G. (E.) trinidadensis* zones with planktonic foraminifera and the *M. murus, M. prinsii, M. inversus, C. tenuis* and *C. danicus?* zones with coccoliths- is that generally utilized by most authors for the Cretaceous-Tertiary boundary succession.

Accurate studies of the biozones show interesting differences in those closer to the C/T boundary. The *M. prinsii* Zone is less well represented in Sopelana than in Biarritz and Caravaca; on the other hand, the *M. inversus* Zone is better represented in Sopelana than in Biarritz.

Thus it is especially difficult to characterize biozones like *Guembelitria cretacea*, whose short duration makes its absence in the stratigraphical record very likely. Maybe, that zone is equivalent to the *G. fringa* Zone as its authors, HERM, HILLEBRANDT & PERCH-NIELSEN (1981), have proposed, basing their argument on the probable occurrence of *G. fringa* specimens, smaller than 0,1 mm, in Caravaca as in Lattengebirge. This is not the case in Sopelana however, because *G. (E.) fringa* occurs at the same levels as *G. (E.) eugubina*, and only in the lower 2–3 cm of grey marls could it be represented.

In any case, it is necessary to remember that the *G. (E.) eugubina* specimens of Lattengebirge have a size of 0,125 m, whereas, in the lowermost *G. eugubina* Zone in Sopelana, we found *G. (E.) fringa* and *G. (E.) eugubina* which were both less than 0,1 mm. Therefore we must ask ourselves if the first occurrence of *G. (E.) eugubina* in Lattengebirge is later than in Sopelana. If the answer is yes then the validity of the *G. fringa* Zone is doubtful, as the key for establishing the *G. fringa* Zone in Lattengebirge lies in the different time of the first occurrence of both species.

When we correlate the Sopelana and Zumaya sections with various parameters, for instance with the percentage of planktonic foraminifera; the number of species of planktonic foraminifera; the nannoplankton, etc. (Figure 6), we find a strong similarity between both sections. In our opinion, the most interesting characteristic which they share are some gradual changes prior to the C/T boundary. These changes were already noted by HERM (1965) and later by ALLEN (1975) and PERCIVAL & FISCHER (1977) in Zumaya. The number of planktonic foraminifera species and their relative abundance suggest changes in the pelagic ecosystem prior the main C/T crisis. In the same way, the calcareous nannoplankton, also provide support for this idea, although with some apparent delay.

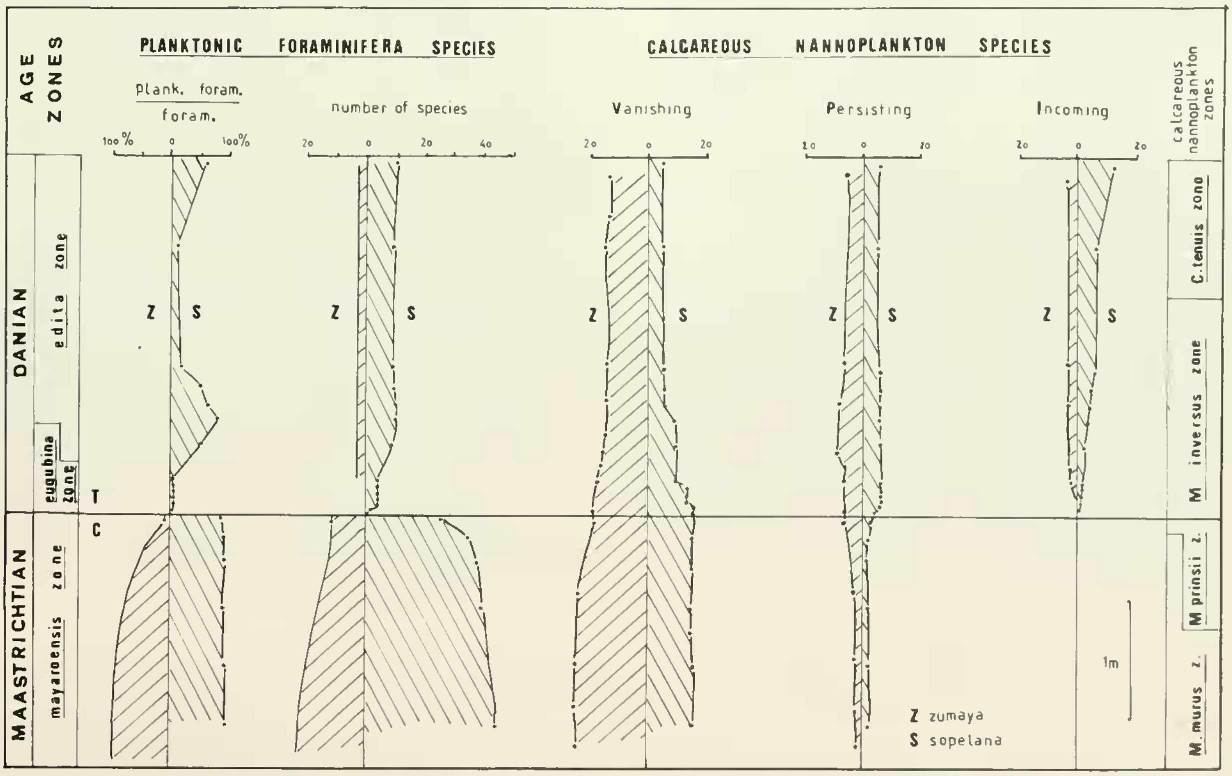

Fig. 6. Comparison between the Sopelana and Zumaya sections by mean of its planktonic microfossils. Zumaya section after HERM (1965), VON HILLEBRANDT (1965) and PERCIVAL & FISCHER (1977).

Therefore, our results are more in agreement with CLEMENS, ARCHIBALD & HICKEY (1981) regarding the nature of Cretaceous-Tertiary crisis, than with opinion centered around the hypothesis of catastrophic or short events.

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